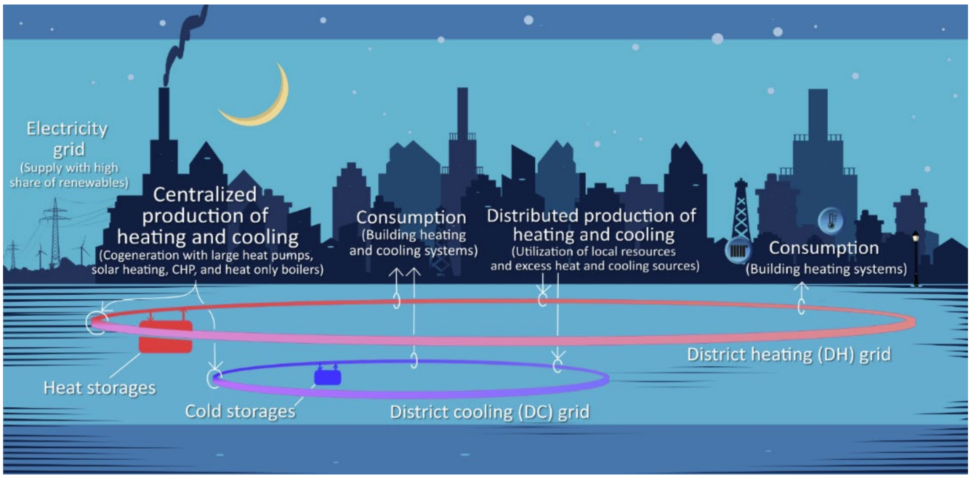
HELSINKI ENERGY CHALLENGE

Final competition entry

BEYOND FOSSILS



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Contents

1 Summary of the proposed solution

The "BEYOND fossils" concept proposal is an energy transition management model based on clean heating auctions. It ensures cost-effective investments in clean heating solutions in rapidly developing low-carbon energy markets and paves up the path to carbon neutral Helsinki in a flexible way. Implementation of the model will end the era of coal by 2029 and reduce the overall greenhouse gas lifecycle emissions by 80%, while energy security is assured simultaneously.

The goal to replace coal by 2029 requires several parallel measures with a very tight schedule. Energy demand needs to be reduced and new clean production capacity has to be installed. To enable this, the best solutions on the market are needed. Energy technologies and solutions are developing rapidly, and the best options today might not be similar to the best ones in 2029. Regular and frequent clean heating auctions is a flexible approach and will enable that the very best heating sources are implemented on a yearly basis.

Open and technology-neutral approach to clean heating auctions is the most cost-effective, innovation enabling, and inclusive approach to reach a carbon neutral Helsinki. Technology-neutrality will maximise the cost-efficiency of the system as it results in the cheapest clean heat sources deployed first due to competition of different solutions, companies, and technologies. It is likely that some solutions turn out to be more competitive than generally thought, or certain unexpected great solutions might appear when the regular markets exist. Technology-neutral auctions will promote the discovery of the most efficient heat suppliers in the best possible way.

From the point of view of the City and legislation (Act on Public Procurement and Concession Contracts), a transparent, and indiscriminatory auction is like any ordinary public procurement. For the implementation of the auctions, we propose the City to establish an executive committee with the mandate to design and organize the auctions with the needed supportive elements. Information about the auctioning criteria, heating grid access and terms, and land use aspects need to be made available well in advance to enable the market entry of different actors and technological solutions. Auctioning criteria, grid connection models and other supportive elements such as energy maps, streamlined permit processes, and expert support need to be provided and evolve hand in hand during the transition period.

From the point of view of the bidders, regular, open, and technology neutral auctions establish a regular market. A successful bid results to a contract where the premium on production will be paid over 10-year period. This creates a regular and reliable income stream that should make many projects bankable and reduce their interest rates, thus further lowering the investment costs.

The Helsinki clean heating scenarios were modelled to evaluate required new capacities, cost impacts, climate impacts, and natural resource impacts of the required investments. The modelling is based on current district heating and cooling system, already decided investments of Helen Ltd, and the provided instructions in competition materials. For the Helsinki clean heating scenarios, we required the model to invest in enough new clean heating capacity to replace the use of coal by 2029 and to reduce greenhouse gas emissions by 80% by 2035 to support the carbon neutrality target of the Helsinki.

If expected energy efficiency improvements in the City of Helsinki's Energy Renaissance program will be realized, 100 MW of new heat production capacity would be needed to phase out the coal by 2029 and additional 100 MW to achieve the 80% target by 2035. With current trends of the district heating demand, 400 MW of new capacity would be needed by 2029 and further 100 MW by 2035. Figure 1 shows the energy balance in these two cases.

According to current technology cost assumptions, the main new technologies would be heat pumps using ground, air, water and excess heat streams as heat sources. There will be significant additional costs in the investment phase, which however lead to reduced energy costs afterwards. The overall heating costs would not increase from the current levels.

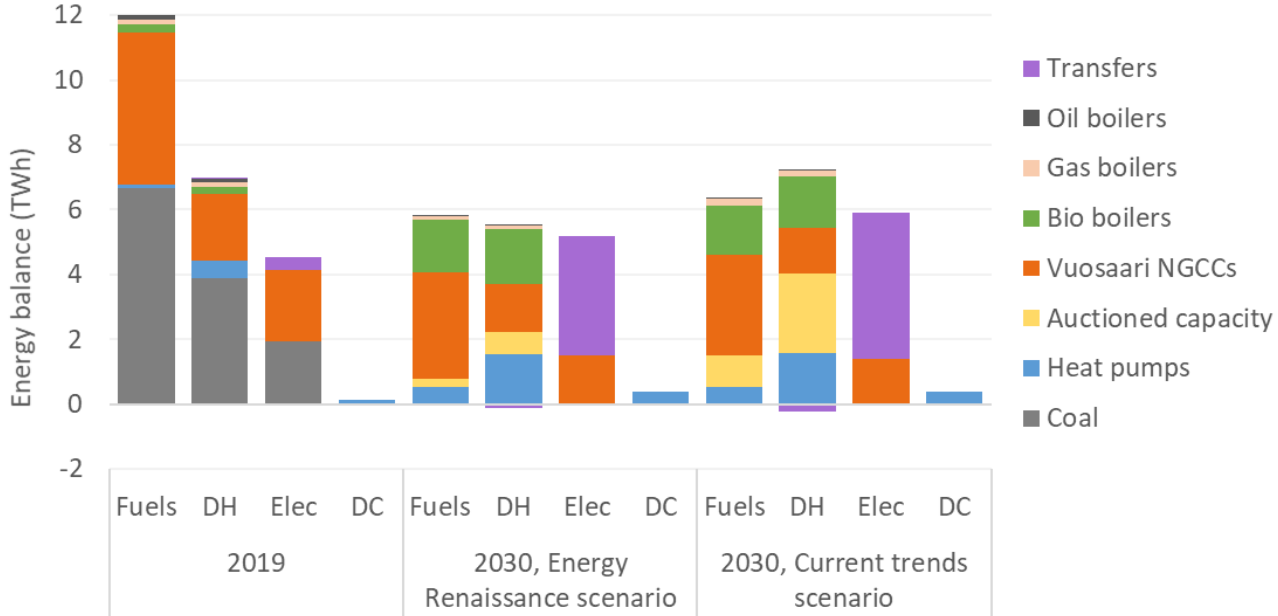

Figure 1. Energy balance of Helsinki's DHC system in 2019 (statistics) and 2030 (modelled). Fuels cover all inputs to generation units: actual fuels and electricity for heat pumps, DH shows district heating supply, Elec shows electricity supply, and DC shows district cooling supply. Transfers cover net imports of electricity and district heating. ***Auctioned capacity is the share that is implemented according to the BEYOND Fossils concept.*** *Other energy production is covered by Helen Ltd from the existing units or investments that has been already decided.*

Auction based approach is extremely well adjustable to updates and new information. Frequent auction rounds and volumes can be increased or lowered depending on the actual development of the heat demand and the performance on previous auctioning rounds.

Auction based approach is a practical model to implement the best technical solutions of the proposals sent to Helsinki Energy Challenge.

2 Climate impact

The BEYOND fossil concept fully phases out coal in Helsinki and 30% of the natural gas in the heating system by 2030 compared to 2019. In total, direct and indirect greenhouse gas emissions from power and heat would be reduced by 75% from 2019 to 2030 and by 80% from 2019 to 2035. The amount of auctioned capacity can be flexibly adjusted to react on changes in the markets or for further support in Helsinki's carbon neutrality target.

The energy and climate scenarios for Helsinki are modelled with a district heating and cooling (DHC) model that covers the production, distribution, and consumption of district heating, district cooling, and electricity (Figure 1). The model operates the production units, distribution grids, and energy storages on an hourly level and satisfies the hourly demand of all energy carriers.

Used DHC model minimizes the operation and investment costs while respecting the energy balances, operation constraints of units and grids, needed reserve capacities, storage sizes and balance, and transmissions from grid-to-grid. DHC model includes Helsinki, Espoo, Kauniainen, and Vantaa, and the modelled scenarios cover all four cities, heat trade between the cities, and foreseeable investments in the region. All units that produce or consume electricity, operate also on Nordpool power markets either selling or buying electricity according to hourly prices. The model also covers CO_2 emissions, external costs including fuel costs, taxes, and emission prices, and operation costs of the units and grids.

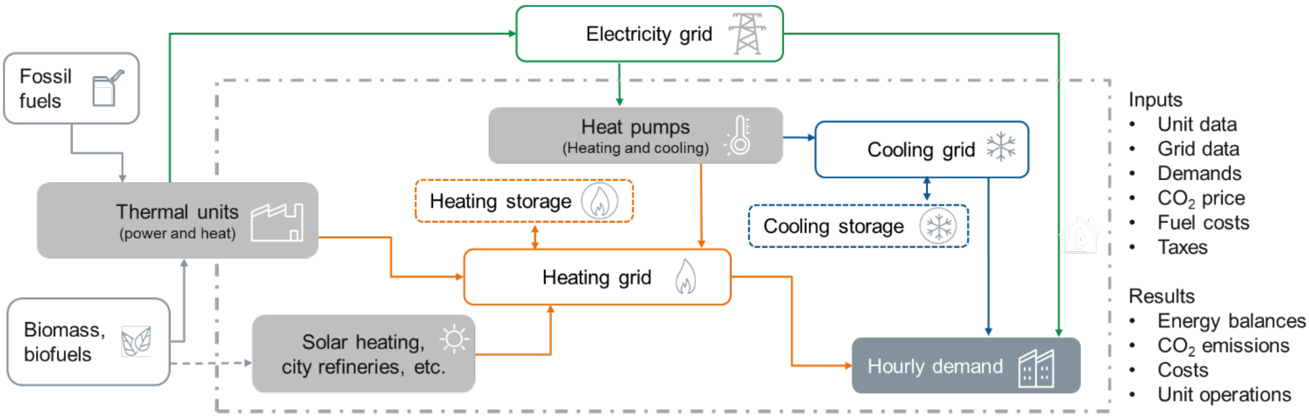

Figure 2. Schematic structure of the DHC model that covers the district heating, district cooling, and electricity market connections.

The Helsinki DHC model has been built, used, and published in earlier research projects and it was adapted to Helsinki Energy Challenge by updating the input data with given instructions. The modelled scenarios include the investment plans that Helen Ltd has already decided, which include expansions of existing heat pumps, Mustikkamaa heat storage, and a biomass unit to Vuosaari. Our scenarios do not include additional biomass-based generation.

The modelled scenario follows the given instructions for the competition entries, but a high risk has been identified regarding the assumed energy demand levels. The technical instructions clearly say that district heating demand of 5.4 TWh in 2030 and 4.9 - 5.3 GWh in 2035 shall be used, which is very ambitious development in the energy efficiency compared to trend in the recent years (Figure 2). Since the Energy Renaissance program is heavily impacting the energy demand levels, the scenario is called "**Energy Renaissance scenario**". However, there is a high risk that expected energy efficiency measures of the Energy Renaissance program will not be fully achieved. To mitigate and to prepare for this risk, we have modelled also an alternative current trends scenario for the heat demand and the required capacity. This scenario is called "**Current trend scenario**"

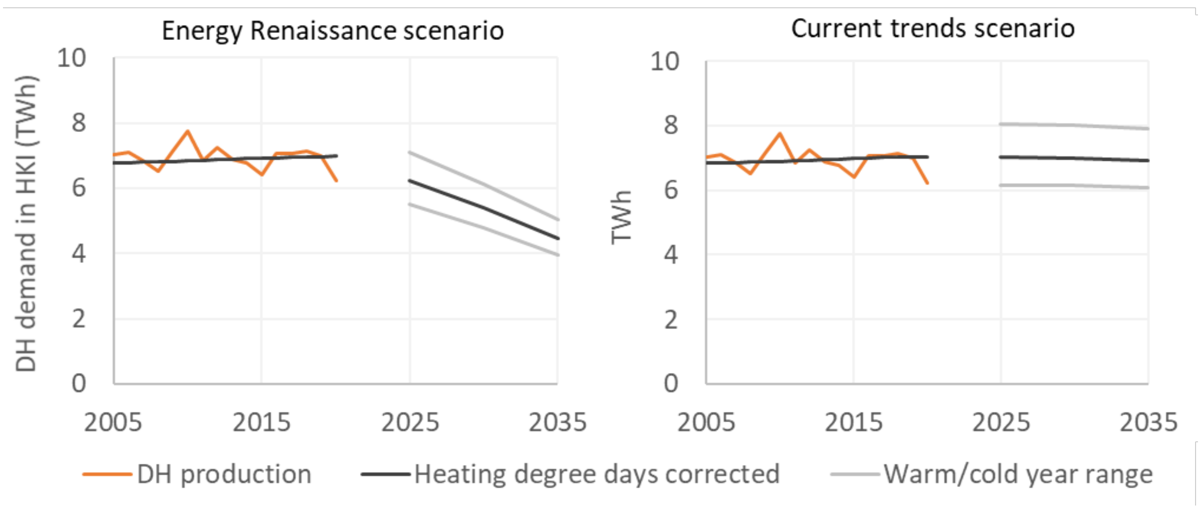

Figure 3. Helsinki's district heating demand in Helsinki Energy Challenge technical instructions (left panel) and current trend (right panel).

Based on this background, we required the model to invest in enough new clean heating capacity to replace the use of coal by 2029 and to reduce greenhouse gas emissions by 80% by 2035 to support the carbon neutrality target of the Helsinki. Since the auctioning process is technology-neutral, the winning technologies cannot be known exactly. With current technology cost assumptions (see chapter 4), the new capacity would be a mixture of heat pumps using ground, geothermal, excess heat, sea water and air as energy sources.

For most of the year, heat pumps have lower production costs than natural gas combined cycle (NGCC) units and are thus dispatched first (Figure 3). The model prioritizes NGCCs during hours with high electricity price as it can sell electricity and avoid buying electricity for heat pumps. In addition, the model uses storages in balancing short peaks and shifting demand to optimize the system operations. The model must respect unit level operational constraints, such as minimum loads, minimum operation times, and partial load efficiencies in all its operations. In addition, the benefits from switching units must be large enough to compensate the start-up and other costs.

The peak demand in winter weeks is produced with natural gas and oil heat only boilers that already exist in Helsinki as peak capacity. Fossil boilers also supply the reserve capacity and produce heat in multiple parts of the grid balancing the local supply, distribution, and demand during the high loads. The peak demand capacity is responsible for the remaining emissions. No new fossil-based capacity shall be installed, and the number of hours the existing ones are in use, shall not grow from the current situation.

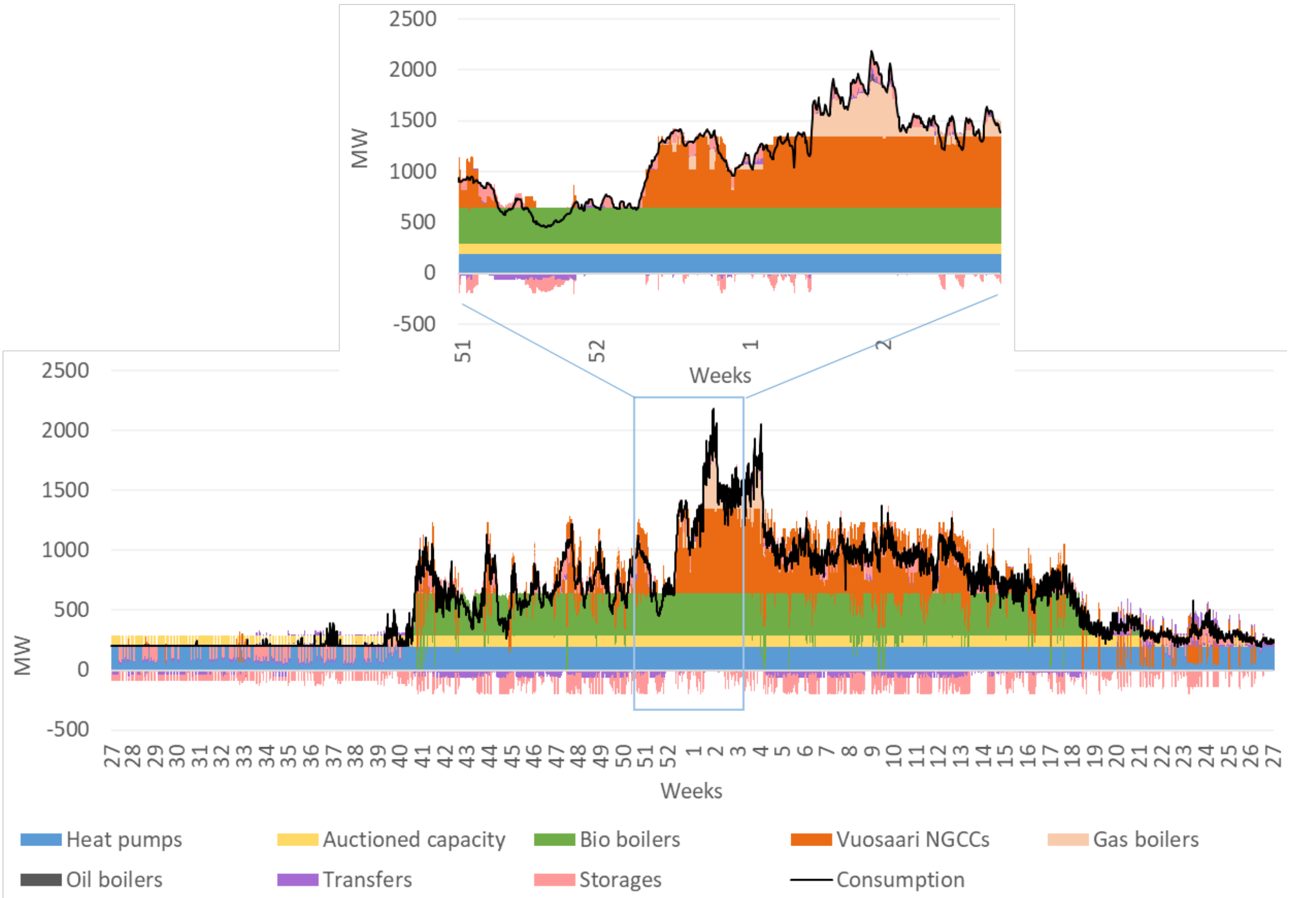

Figure 4. Hourly operation of DH units in the City of Helsinki in 2030 in Energy Renaissance scenario. Zoomed in during a warmer Christmas and colder first weeks of the year.

Note: We have used given time series but modelled the year from summer to summer for better representation of large heat storages currently under construction.

The climate impact consists of direct CO_2 emissions from the burning of fossil fuels and reduced indirect life cycle emissions from the fuels. We have used official emissions factors from the Statistics Centre of Finland to calculate direct emissions. Indirect emissions are calculated with factors based on scientific literature[1, 2]. Indirect emission factors for fuels include processing and transportation, but not the possible changes in the forest carbon stocks. Indirect emissions of bought electricity is assumed to be 30 gCO_2/kWh as in competition instructions. Together these are (direct + indirect emissions): coal 310 + 58 gCO_2 eq/kWh, natural gas 200 + 46 gCO_2eq/kWh, and oil 265 + 55 gCO_2eq/kWh, biomass 0 + 40 gCO_2eq/kWh, electricity 0 + 30 gCO_2eq/kWh.

With these factors, the largest climate impact comes from decreased use of coal. Helsinki used 6.7 TWh of coal in 2019, which is completely phased out in our scenarios. In total, the lifecycle GHG impact (direct + indirect) of the coal phase out is -2.5 $MtCO_2$eq. The second largest impact comes from the reduced use of natural gas (-0.4 $MtCO_2$eq) and third largest from the increase in purchased electricity (+0.1 $MtCO_2$eq). Heat pumps increase the amount of purchased electricity by directly increasing electricity demand and indirectly by reducing the local CHP production from both coal and natural gas CHPs. Additional climate benefits arise from reduced use of biomass and oil. The climate impacts is the same in both modelled scenarios, but the required amount of auctioned capacity changes. The use of biomass will not increase due to the implementation of the BEYOND fossils concept.

The direct CO_2 emissions decrease from 3.1 $MtCO_2$ in 2019 to 0.7 $MtCO_2$ in 2030. This equals 80% reduction. Converted to emission intensity of the district heat, **which improves from 200 gCO_2/kWh in 2019 to 90 gCO_2/kWh in 2030 and to 60 gCO_2/kWh in 2035**. Additional lifecycle emissions from the production chains of the fuel and the bought electricity increase the total emissions by 0.6 $MtCO_2$eq in 2019 and by 0.2 $MtCO_2$eq in 2030. Calculating with lifecycle emissions, GHG intensity of produced district heating would be improve from 250 gCO_2eq/kWh in 2019 to 120 gCO_2 eq/kWh in 2030 and 90 gCO_2eq/kWh in 2035.

3 Impact on natural resources

The BEYOND fossils has a significant positive impact on natural resources through reduced use of fossil fuels. Investing to a new capacity requires some resources, but these volumes are significantly smaller than savings in the use of fuels.

The impact on natural resources consists of impacts on used fuels and required materials in the investment phase and is estimated based on the modelled scenarios. The auctioned capacity reduces the use of fossil fuels and biomass in district heating production. In total, the use of coal is reduced by 100% and the use natural gas by 50% compared to 2019. In other units, the amount of replaced coal is 7 TWh (statistics 2019) equaling roughly 930 kt of coal each year (assuming 7.3 MWh/t). The amount of replaced natural gas is 1500 GWh in 2030 (145 Mm^3, 110 kt), compared to 2019 and assuming conversion factors of 100 m^3 per MWh and 49.3 GJ/t as for LNG. Table 1 presents a summary and the impact in other years.

Oil remains as a backup fuel in the system, as the required volumes are quite low. The use of oil would remain on current levels on average and depend mostly on how cold each winter would be. The new Vuosaari biomass unit would increase amount of used biomass from 200 GWh to 1600 GWh in 2025. However, our solution does not propose any new biomass units and the auctioned capacity would reduce the use of biomass in the biomass boilers by 200 GWh from 2025 to 2035. This equals 22 kt of forest chips annually assuming 4.6 MWh/t energy content.

[1] Sokka L, Correia S, Koljonen T. Lämmityspolttoaineiden tuotannon elinkaariset kasvihuonekaasupäästöt. VTT Technology 336. 2018.

[2] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast). 2018.

Table 1. Natural resource impact as reduced annual fuel use

Fossil fuels and biomass	2030 [kt / year]	2035 [kt/year]	2040 [kt/year]	Domestic share of each material group
Coal	- 930	-930	-930	0 %
Natural gas	-110	-170	-200	0 %
Wood	-22	-44	-60	50 %

The amount of required materials in the construction phase highly depend on the actual winning technologies in the clean heating auctions. The scenario excludes technologies which rely on burning fossil fuels or biomass and forecasts the growth of heat pump technologies as they are currently the most cost-effective solutions. However, technological innovations may lead to the high cost-efficiency of e.g., geothermal, fuel cell, nuclear, solar, power-to-X and energy efficiency technologies, so it is impossible to categorically rule out any specific fuels. Nevertheless, any investment requires natural resources, and the share of different raw materials depends on the chosen technology.

Clean heating solutions require natural resources. We have estimated the raw material requirement for our modelled scenario based on different heat pump technologies using environmentally extended economic input-output model. Raw material requirement (RMR) includes the raw materials extracted from domestic environment and imports of products measured as the total of all raw materials required along the production chain (raw material equivalence). RMR indicator includes all materials extracted domestically or abroad in order to manufacture the needed products and services (direct and indirect material inputs).

Investing 100 MW capacity of heat pumps between 2021-2030 and additional 100 MW capacities during both 2030-2035 and 2035-2040 requires altogether 336 kilotons of raw materials including all direct and indirect material use. Most important raw materials are metals, soil materials and fossil fuels. Based on the structure of Finnish economy in 2015, 66 % of required raw materials are imported and 34 % of raw materials are extracted from Finland. Raw materials needed in the modelled scenario are assumed to be available and common reflecting the fact that the technologies have high technological readiness level.

The land use (both on the ground and underground, i.e., boreholes) depends once again on the results of the auctions, so exact land use is difficult to determine. The anticipated solution is expected to be dispersed and it shall require boreholes for heat pumps, retrofitting buildings, larger heat pump stations and possibly small-scale plants. The land use must be planned concurrently with auctions (cf. details in section “Implementation feasibility”).

Table 2. Natural resources required when building the new auctioned capacity in the modelled Energy Renaissance scenario, which indicates the need of 100 MW of new capacity until 2030 and additional 100 MW capacities during 2030-2035 and 2035-2040 periods.

Raw material requirements for building the auctioned capacity	2021-2030 [kt]	2030-2035 [kt]	2035-2040 [kt]	Domestic share of each material group
Metals	53	53	53	1 %
Soil materials	27	27	27	97 %
Fossil fuels	14	14	14	7 %
Wood	9.5	9.5	9.5	79 %
Construction minerals	5.5	5.5	5.5	31 %
Industrial minerals	3.1	3.1	3.1	29 %
Crop	0.5	0.5	0.5	49 %
Total	**112**	**112**	**112**	**34 %**

4 Cost impact

The "BEYOND fossils" concept is designed to achieve greenhouse gas reductions by lowest possible costs using the auctioning mechanism to identify the most cost-efficient energy solutions and heat sources. There will be significant additional costs in the investment phase, which however lead to reduced energy costs afterwards. The overall heating costs would not increase from the current levels. Auctioning approach splits the investment cost between the investor and the City that pays a premium. National investment subsidies and funding for phase-out of coal will further reduce costs. In addition, this approach enables the inclusion of new lower cost technologies under development.

The modelling covers the following cost categories and components:

- Operation and maintenance for existing and new capacity: costs of fuel and purchased electricity, profits from sold electricity, unit maintenance and operation costs, taxes, CO_2 price, energy losses in transmission and storage
- Investment costs of new capacity and required grid connections
- Decommission costs of the phased-out capacity

Fuel prices, electricity prices, taxes, and CO_2 prices listed in the Helsinki energy challenge detailed instructions were used. Unit specific data for existing units, such as capacities, efficiencies, operation and maintenance costs, are from Finnish district heating statistics, environmental permits of each unit, and other public info of the units[3, 4, 5]. Public data has been supplemented with data from DEA's Technology Data for Generation of Electricity and District Heating[6]. We use DEA's data also for future investment options to model the potential investments in our scenarios.

Operation costs are calculated on an hourly basis for each year (see Figure 2). Annual maintenance costs of old and new units have been included in the calculations with a flat rate of 2.5%/year of investment cost for each unit. These annual maintenance costs include required regular maintenance and replacing wearing parts when required. Decommission costs of phased out units need to be included to cost estimates and we assumed that those would be 10% of the investment cost of a similar new unit.

Investment and decommissioning costs are annualized with 4% real interest rate and 25 years (as per the instructions). Many units can operate longer, and the 25 years assumption does not stand for the technical lifetime of the technologies and solutions. Thus, the reduced operation costs would bring benefits longer, but this is a really long-term perspective and not included in our analysis.

With the listed assumptions, the new modelled capacity was a mixture of geothermal heat pumps, excess heat, large air-source heat pumps, and sea water heat pumps. All these are mature technologies with operating units in Finland and have multiple domestic suppliers, guaranteeing a liquid and competitive market.

The split of these technologies is not presented, as the actual auctioned capacity will be with different mix of these and possibly other technologies. The scenarios present a modelled estimate of the impacts of the auctioned capacity. The actual technology parameters are always site-specific and can have lower or higher values than assumed here, but the auctioning model is designed to let the market identify the best combinations of sites, actors and technologies.

[3] https://aaltodoc.aalto.fi/handle/123456789/14774
[4] https://www.friotherm.com/wp-content/uploads/2017/11/katri_vala_e012_uk.pdf
[5] https://lutpub.lut.fi/handle/10024/156482
[6] https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-generation-electricity-and

The modelled total system cost first increases during the investment phase (Table 3), but turn to a decreasing path due to more efficient production technologies, avoided taxes on fossil fuels, avoided emission payments, and building sector energy efficiency measures (Table 4). The overall system costs remain in the current level as well as the average cost of produced heat.

Table 3. Modelled investment costs for modelled 5-year periods in Energy Renaissance scenario. All sums are in 2020 currency. Modelled investment costs are presented here as overnight costs and annualized in the following table.

		2020-2025	2025-2030	2030-2035
Investment costs, Helen's already decided investments	M€ / 5 years	306	0	0
Investment costs, auctioned capacity	M€ / 5 years	39	39	78
Decommission costs	M€ / 5 years	90	50	36

Table 4. Annual total costs for the City's district heating and cooling system in Energy Renaissance scenario. Operation costs include auction premiums. All sums are in 2020 currency.

		2020	2025	2030	2035
Annual operation costs	M€ / year	169	184	162	157
Annual maintenance costs	M€ / year	95	81	69	62
Annualized investment and decommission costs (4%, 25y)	M€ / year	0	28	34	41
Total costs of the DHC system	**M€ / year**	**264**	**293**	**265**	**260**
Average heat cost	**€/MWh**	**42**	**43**	**43**	**41**

Costs, savings, and profits will be shared between customers, the City, Helen, and investors who win auction bids. Most importantly stable overall system cost and stable heat production should be interpreted as stable heating costs for customers.

The City's costs consist of auctioned premiums and the costs of running the clean heating platform. The level of required premiums could be estimated based on modelled additional systems costs and on subsidy levels in similar schemes.

Business Finland gives investment aid for different kind of energy investments. Aid is for example 15 % to companies or municipalities investing in heat pumps and 20 % to solar heat projects. Ara (The Housing Finance and Development Centre of Finland) gives 20-25 % investment aid to municipalities getting rid of oil heating. Based on these subsidy levels we estimate that premium in auctions would be around 20 % after few rounds. The total estimated costs for the auctioned capacity are 156 M€ (table 2). With a 20% premium level the costs for the City of Helsinki would be 31,2 M€ for the time period 2022-2035. This is in average 2,3 M€ per year.

The costs of running the platform can be calculated as 5-10 full time persons salary or purchasing the similar amount of expertise from outside experts. The estimation of these costs is 500 ke - 1 M€ per year. In total, the estimated costs for the City of Helsinki until 2035 would be 46 M€.

The total costs for the City of Helsinki until 2035 is 46,2 M€.

However, actual costs will depend highly on the actual development of the Energy Renaissance program. If the targets will be reached, the annual costs would remain in the current levels as shown in Table 2 and Table

3. If the district heat demand develops as in the Current trends' scenario, there is a greater need for the new capacity that increases the required investment costs. In this case, the modelled investment costs increase from 160 million to 750 million and the total systems costs and the average cost of the produced heat would increase 10% from 2020 to 2030 and 15% from 2020 to 2035. In this case, the costs for the city would be approximately 170 million from 2020 to 2040.

The investments in clean heating solutions shall induce economic activity in Finland. The modelled scenario of 300 MW of heat pumps until 2040 would increase economic output by 306m EUR (in real 2020 prices), including direct and indirect effects. The value added would increase by 125m EUR and the employment impact would be almost 1900 employees during the investment phase. Construction sector (40 % of employees), mechanical engineering (24 %), and administrative and other business support activities (11 %) are the main industries for additional employment impact. This economic activity will have a positive impact on both municipal and government tax revenues, too. The domestic share of investment goods and services are estimated to be 75 % of the whole investment sum. The economy-wide impact results are estimated with input-output model.

5 Implementation schedule

There is only 14 years of time left for the City of Helsinki to reach the its carbon neutrality target set for 2035. Therefore, the City should aim to get clean energy auctions up and running within one year. After launched in 2022, it is important to have as frequent auctioning schedule as possible to help the supply chains of the clean energy solution providers to adapt, and the investors to plan the projects efficiently. The progress will be followed up constantly and the auctions adjusted accordingly when needed, to make sure the goals are met.

The figures below illustrate the timeline of the Helsinki energy transition, years when coal plants will be phased out and how the clean energy capacity is needed to replace the closing plant capacity. The new capacity needs to be built beforehand to avoid energy supply and security challenges. As energy investments require time for project development and design, permitting, auctioning, component manufacturing and installation, the auctions need to be initiated as soon as possible.

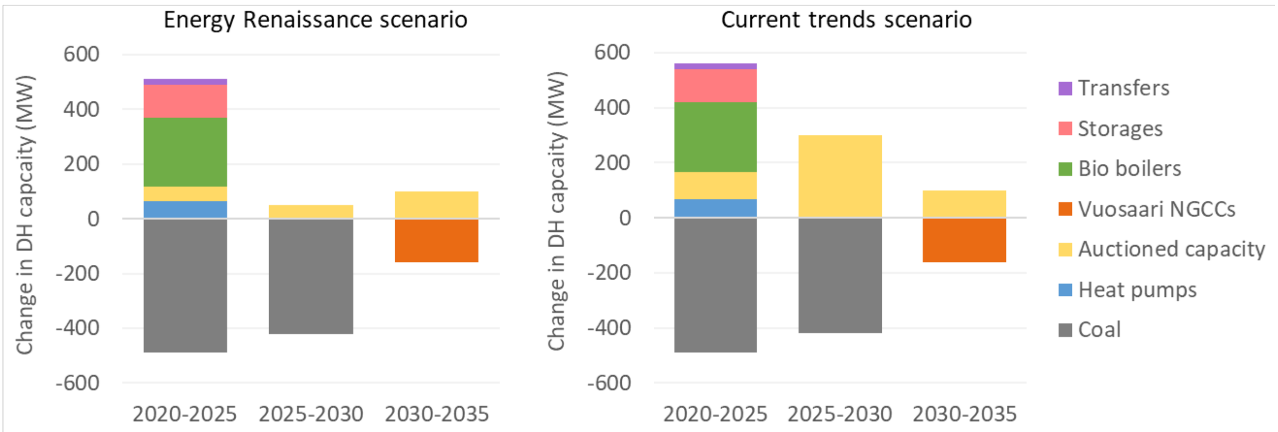

Figure 5. Changes in the district heating generation capacity in modelled scenarios.

The Figure 6 below illustrates how the auctions will be developed and run by the Helsinki clean heating executive committee (see chapter 6.1 for a description of the executive committee), and how the system can evolve during the 14 years of the transition period 2022-2035. The executive committee should aim to get clean energy auctions up and running within one year. After its launch in 2022 the installation rate of new capacity shall be a minimum of approximately 15 MW/year based on the Energy Renaissance scenario. Volume in the auctions could be a little less in the beginning to warm up the market and to give time for supportive actions to be ready to help the investors.

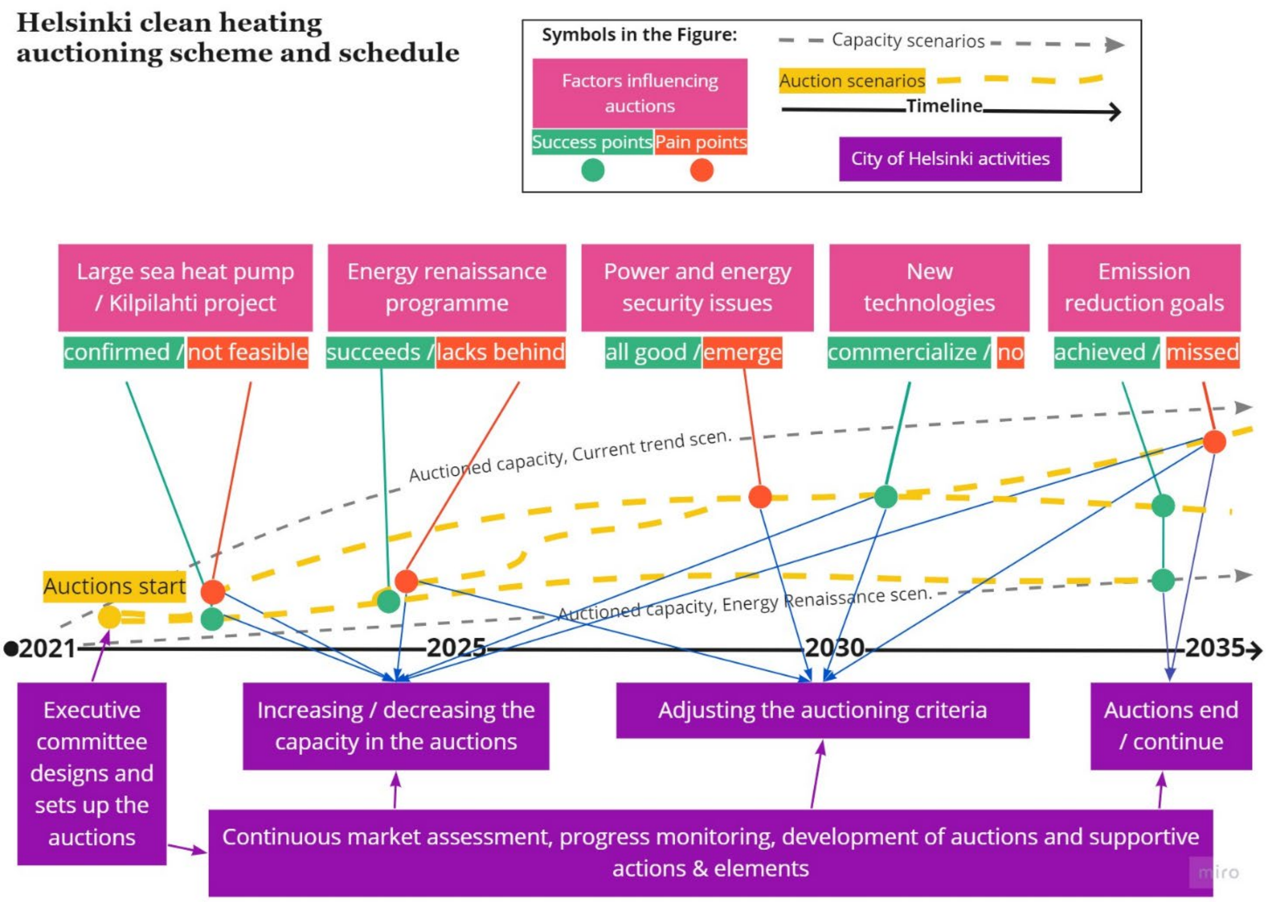

Figure 6. Clean heating auctioning schedule and flexible implementation scheme

The realised installation rate will be followed up constantly. The required heating capacity is heavily dependent on the success of the City of Helsinki's energy renaissance programme according to our sensitivity analysis. If the projected energy efficiency improvements are not met, the target levels for the auctioning will be raised, respectively, to ensure sufficient heat production capacity to meet the demand. Therefore, the capacity to be auctioned will be adjusted based on continuous follow up of the realised capacity additions, and success and pain points during the transition, as illustrated in the Figure 6.

It is important to have as frequent auctioning schedule as possible to help the supply chains of the clean energy solution providers to adapt, and the investors to plan the projects more efficiently. Auctioning projects e.g. only once a year can cause negative market impacts, such as temporal high and low demand periods in the supply chains, causing unwanted bottlenecks and e.g. price and labour demand fluctuations. Frequent auctions will also lower the threshold for bidders to participate as they know that even if they are not successful at the first attempt, there will be further auctions soon where they can participate again by adjusting their bids according to the market information from the previous auctioning rounds. Frequent auctions will also provide more market and price transparency, provide flexibility in project development, and make the market more liquid. This way there will always be several rounds of successful bidders implementing their projects in parallel, and therefore stable and predictable market conditions.

6 Implementation feasibility

The clean heating market platform is managed by a clean heating executive committee which is supported by a steering committee, both with clearly defined decision-making power. The City of Helsinki is the owner of the platform and is responsible for forming and chairing the executive committee. In this section a potential auctioning scheme for clean heating in the City of Helsinki is outlined. Supportive actions including energy source maps, fast-track permit process and suport for connecting to district heating network is also explained.

6.1 Organisation of the clean heating market platform

A clean heating executive committee manages the clean heating market platform. The executive committee needs to be flexible and fast to ensure a rapid implementation of the auctioning scheme and its supporting activities. It needs to be authorized to make decisions that are needed for a successful implementation of the platform. The City of Helsinki is the owner of the platform and is responsible for forming and chairing the executive committee. The executive committee consists of experts on the task depending on the expertise they bring into the group and their role in it. The following expertise will be included: technical, financial, legal, urban planning, and project management expertise. The executive committee reports to the steering committee.

A steering committee will be formed to provide oversight, strategic guidance and support on the activities that are executed by the executive committee. The executive committee shall be able to work with a decision-making power to achieve emission reduction goals within the general boundaries set by the City of Helsinki. The steering committee, which is led by a representative of the City of Helsinki, consists of representative from the urban planning department, Helen Ltd, decision-makers, experts and other relevant parties. The steering committee meets 2 times per year and more often if requested by the executive committee. The executive committee can request the meeting if there is for example a need for urgently adjusting general boundaries, or urgent support or advice. The authorization division between steering committee and executive committee shall be clearly defined before launching the platform.

The auctions will be split into two categories: A: self-consumption and B: grid connected solutions (see chapter 6.2 for further description). The reasoning for this is that the nature of the off-take arrangement of the heat is fundamentally different.

In case of network-connected projects successful bidders (energy or technology companies) would supply heat to the distribution network, and Helen would pay for the generated heat according to their open heat purchase prices varying over the seasons. In this case, the auctioned product is a price premium to be paid by the City of Helsinki on top of the heat market prices paid by Helen Ltd. In self-consumption category, the heat is supplied for self-consumption off a housing company and the bidder would be either the housing company itself or for example an energy service company implementing the project. In self-consumption category the City of Helsinki would pay investment subsidy type of premium to lowest bids based on €/kW.

Auctions will be continuously analysed, and in later rounds for example location-specific incentives can be added as seen feasible. Such foreseen changes should be communicated to the market early on, already when they are being considered, in a transparent manner, to allow the market to properly adjust to these changes. Further requirements can be introduced to both categories when learning from the previous auctions. For example, in category B there could be an obligation to produce heat with full capacity when outside temperature reaches a certain limit.

The process of the platform is visualised in Figure 7 including supportive measures that are described in chapter 6.3 The process is described in detail in the following chapter, 6.2.

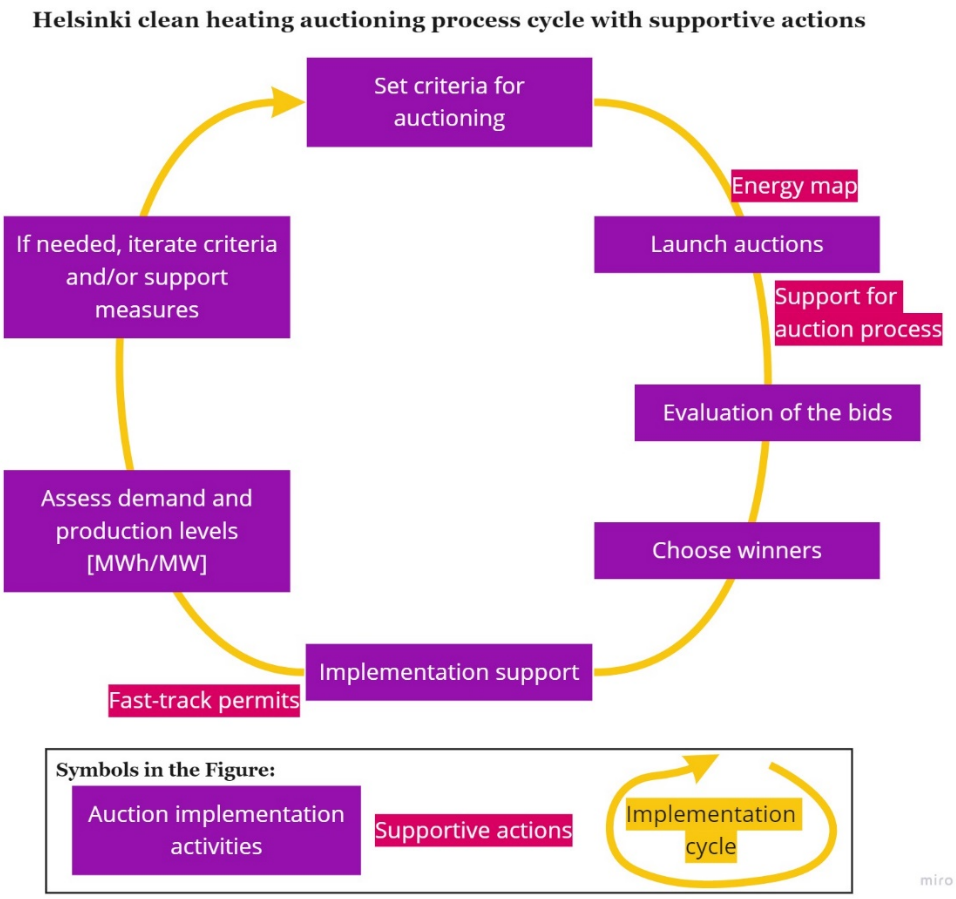

Figure 7. The process of the clean heating platform.

6.2 Clean heating auctions

Auctioning of clean electricity generation has become a mainstream instrument to ensure investments during the latter half of the last decade. There is a vast amount of international experience and evidence on how these auctions can be arranged successfully. It is possible to utilise the same mechanism in the heating sector too. In this section a potential auctioning scheme for clean heating in the City of Helsinki is outlined. We elaborate the scheme as much as possible to prove the realism and provide concrete options for implementation, while also acknowledging that the detailed design of the scheme needs to be properly resourced and implemented by Helsinki clean heating executive committee in the beginning of the implementation. This proposal serves as a basis for a more detailed design.

There are numerous ways of conducting the auctions. We present the one we think could result in the best outcome with the lowest costs to all stakeholders. In the design options of the auctioning scheme, we apply the approach developed by the International Renewable Energy Agency (IRENA), which has carried out extensive work on analysing renewable energy auctioning schemes globally since 2012[7]. While this approach is designed mostly for auctioning renewable electricity, we apply and modify it in the heating context. The main aspects to be considered in an auctioning scheme are the following, and these will be discussed one by one in the following chapters.

[7] https://www.irena.org/policy/Renewable-Energy-Auctions

6.2.1 Auction specifications

In renewable electricity auctions it is typical that the bidding involves energy [kWh], and the winners are selected based on who can provide electricity at the lowest price per kWh. In case of heat, it is important to further ensure that the installed capacity [kW] will be sufficient to respond to the heat demand when the demand is at its highest in winter. Therefore, attention needs to be paid to the capacity in addition to energy.

Theoretically, a technology-neutral competition for all solutions should lead to the most cost-efficient result. However, in practice, there can be several reasons why it will be more efficient to auction different types of projects separately. In heating auctions, there are two reasons to splitting the auctions into two categories. Firstly, it can be bureaucratic to pay small premiums over a long period of time for small-scale actors who mainly produce the heat for their self-consumption. On the other hand, for heat producers connected to the heating network, it is better to encourage production over time.

The auctioning will be organised as technology- and location-neutral in two categories as the following:

Category A: clean heat production that is connected directly to a building or to a local heating network. Auctioning is based on capacity.

Category B: clean heat production connected to the district heating network. Auctioning is based on energy.

In category A there is no risk for the installed capacity not being used to its full potential, since the solutions are building / building group specific. If these systems are not producing heat, there will be no heating energy available for the end-users. Therefore, the product to be auctioned in category A is installed heating capacity, measured in kW, in -15 ℃ temperature. The temperature level -15 is chosen as a result of a compromise between investment costs and the performance of the energy system in cold weather. According to statistics of Finnish meteorological institute it is typically 50-150 hours per year (0,6-1,7%) colder than -15 C in Helsinki.

In category B, where producers feed the energy in the district heating and cooling grid, it is more feasible that the auctioning product is energy [kWh]. This eliminates the risk of auctioning winners not running the systems as much as is techno-economically feasible and measuring of produced energy is easy when the heat is supplied to the network. Therefore, the product to be auctioned in the category B is produced energy, measured in kWh. Since the auctioning scheme is based on capacity the capacity in -10 C temperature shall be given by each bidder. The temperature level -10 ℃ is chosen as a result of a compromise between investment costs and the performance of the energy system in cold weather. In category B the system can rely on existing oil-based boilers as back up if needed which justifies a higher temperature level than in category A. According to Finnish meteorological institute it is typically 100-400 hours per year (1,1–4,6% of the year) colder than -10 ℃ in Helsinki.

The auctioning volume should be based on the difference between the existing clean heating capacity and the targeted clean heating capacity. There needs to be a series of auctions during the next 14 years period (2022-2035), and the auction volumes need to match the target. In addition to the total cumulative additional capacity, it is important to consider the current market size as the starting point, i.e. how much the market can deliver annually. It may be justified to arrange smaller auctions in the beginning, thereafter, increasing the auction volumes gradually and in a foreseeable and transparent manner, to allow the market to respond to the growing demand for project implementation. If the initial annual auctioning volumes are much larger than the current annual market, there is a risk of bottlenecks, such as drilling capacity, personnel, or other, and that the market is not able to respond to the demand.

There will be two auctions per annum in both category A and B. Frequent auctions are important as it lowers the threshold to participate, as the timing of participation is more flexible, and it is also possible to re-submit and adjust unsuccessful bids based on the market information from previous rounds. It will also enable more even and stable distribution of work in the supply chains, instead of large volumes auctioned less frequently.

There will not be a minimum project size for individual bidders as a starting point. However, there will be a maximum size in to ensure liquidity. Every second or third year a large-scale project auction (up to even very large projects of tens of megawatts) would be auctioned in category B. Even if the volumes are split across a large number of auctions and therefore the total volumes in individual auctions relatively small, it is important to offer large-scale demand occasionally so that large-scale solutions can also participate in meeting the objectives. If the Helsinki renaissance program is not 100% successful (scenario moving towards Current trend scenario) there will be a larger amount of capacity needed and larger scale solutions will be needed.

An S-curve auctioning volume can be established, starting approximately from the current market size, and then gradually increasing the auction volumes, and eventually evening out the volumes in the final few years of the auctions scheme.

To warm up the market, the auctioning can start with small 1-2 MW per round in category A, and with slightly bigger capacity levels in category B, and gradually increase and adjust the volume during the 14 years' period. There needs to be an initial volume plan for the whole 14 years' period to give visibility for the market players. During the period, even if the volumes need to be adjusted from time to time, the volumes should always be fixed for at least 1-2 years ahead at each point of time, and changes to volumes (and other terms) should only apply with a sufficient lag to enable the market to adjust to these changes.

6.2.2 Eligibility criteria and qualification requirements

The auctions are in principle technology-neutral, but minimum environmental and quality criteria must be defined in order to secure desired outcomes regarding emission reductions, air quality, biodiversity, forest carbon sinks, social justice etc. For example, unsustainable biomass incineration solutions can be excluded and peak power management solutions can be included in the scope of the auctions with eligibility criteria.

One of the reasons why auctioning goals may fail is that the requirements from eligible bidders are too loose, and some of the successful bidders are eventually not capable of implementing their projects. As a starting point, anyone should be eligible to submit a bid. Typically, these could include housing companies, energy service companies, energy utilities (including Helen), real estate investors and managers, and other investment companies, for example.

The executive committee will develop detailed criteria about needed documentation by the bidders. The aim is to keep the auctioning process as light bureaucratic as possible while ensuring that the bidders' technical and financial capacity can be properly assessed. The technical details of the proposed solutions need to be explained by the bidders to ensure a qualitative assessment of the bids. Templates and clear instructions should be provided, and they will be iteratively updated to the next auctioning rounds based on feedback received from the bidders. Bidders can be required to present evidence of their technical and financial capabilities. The bidders can demonstrate sufficient *technical capabilities* by specifying their track record. For example, in case of a housing company as a bidder, there could be a requirement of having a credible energy service or other company included in the proposal, who will have a turnkey responsibility in implementing the project. The bidders can demonstrate the *financial capability* to implement the project by providing a credible financing plan. This could include for example providing evidence of cash or cash equivalents available to finance the project, or for example housing companies providing evidence of the capability to obtain a loan from a bank to finance the project.

Sometimes auctions consider also various other socio-economic aspects. For example, some countries may want to develop domestic industries and supply chains and may therefore include a requirement for domestic content in projects. Such a requirement would be difficult to include in public auctions due to current public procurement legislation. It could also be possible to add for example requirement to employ a certain amount of unemployed people. While such requirements can bring broader benefits, according to IRENA's analysis, they also tend to lead to higher bidding prices and sometimes to other challenges. Such additional requirements and objectives should therefore always be very carefully considered and analysed before implementation. As a starting point no other socio-economic aspects than the bidders' capabilities and projects' own merits in the auctioning will be included. Such additional aspects can be considered in later auctioning rounds if needed. In such case it is of utmost importance to have a very transparent and predictable process of considering and including such additional aspects, in order to allow the market to adapt to these additional requirements well in advance.

6.2.3 Winner selection and contract award process

There is a vast amount of experience in clean energy auctions internationally, and it is suggested that a more detailed analysis of such procedures is carried out when implementing the auctioning scheme. In this case, however, it must be noted that the frequency of auctions will be high, and it is likely that there will be a large amount of small bidders participating in these auctions. Therefore, particular emphasis needs to be put on the efficiency of the procedure. As a contrast, in auctions where a limited group of pre-qualified bidders compete of one large project the procedures can and must be much more robust and tailored. Although different in many ways, it could be relevant to evaluate the applicability of the renewable electricity premium tariff auction scheme and the traffic infrastructure aid implemented by the government of Finland and administered by the Energy Authority of Finland. Also, the existing municipal public procurement procedures should be applied to the extent possible.

The procedure should be fully online, and all parameters as much standardised and automated as possible, in order to process a large amount of small bids. We also propose, to make the process faster and easier for bidders, that the City of Helsinki supports auctions with several complementary measures.

The winner selection shall be purely price-based, and based on "pay-as-bid" approach. This choice is justified as there is a strong need to maximise the efficiency of the bidding procedure, and there is no compelling reasons to add other scoring criteria to the winner selection. Criteria such as bidder and project quality, socio-economic aspects, etc., need to be included as eligibility criteria to participate, but not in the scoring of received bids.

6.2.4 Payment structure

The payment structure will be based on installed capacity in category A and produced energy during 10 years in category B.

The bidders in the clean heating auctions in category A will offer a capacity [EUR/kW] "premium price" that they require in order to implement the project. For example, a bidder with a project of 45 kW clean heating capacity could bid investment price premium (EUR/kW), that is needed to make the project feasible. The bidders will offer a premium price which is on top of the direct investment cost paid by the investor (e.g. housing company). Since the auctioning in category A is based on capacity, the payment can be made as an investment premium and the whole amount can be paid upfront when the project is implemented and operating.

In category B (projects supplying heat to the district heating network) auctioned capacity will be included in the open district heating tariff system, and the bidders will bid for a *price premium (EUR/MWh)* on top of the open district heating tariff during heating season. The premium contract time is 10 years. The open district heating tariff system currently defines the heating season as seven months covering autumn, winter and spring. During each heating season during the contract time, the bidder has guaranteed access to the grid and can produce and sell energy according to agreed tariffs and premium.

In theory the premium can be very small or even zero if the bidder evaluates that the project is economically feasible. The bidder would also in this case benefit from lower interest rates guaranteed through long term 10 years contracts (category B) and the supportive mechanisms (see chapter 6.3).

In the capacity-based auction in category A, the payment the whole bid amount shall be done upfront at the commissioning of the project, after confirmation that the installation meets the technical specifications based on which it was approved. Effectively, therefore, the auction in category A becomes an auction of an investment premium.

In the energy-based auction in category B, the payment shall be an energy based price premium on top of the market price according to the actual heat production.

6.2.5 Bonds, sanctions and risk analysis

One of the most important reasons why auction schemes have failed is that the successful bidders do not have sufficient incentives to implement the projects after having been awarded a contract. To this end, successful schemes tend to include bid and completion bonds to ensure that the bidders will implement the projects if they are successful. Bidders must place a small bid bond (such cash pledge or letter of credit from a bank) when they submit a bid in the auction. The beneficiary of such bond is the auction administrator. Bidders will receive the bid bond back after the results have been confirmed. Successful bidders, however, have to replace the bid bond with a larger completion bond, in order to release the bid bond. They will only receive the completion bond back when the project has been implemented and commissioned, and after it has been confirmed to meet the technical and operational specifications as set out in the bid. If the project is not implemented, the bidder loses the entire completion bond, and if the project is implemented but does not fully meet the technical or operational specifications, the bidder will lose part of the completion bond.

The clean heating auction shall include both bid and completion bonds to ensure that the participating bidders are serious with their bids, and that the successful bidders will actually implement the projects as bid.

While the meaningful size of such bonds should be analysed in more detail, typical levels or order of magnitude could be around 1% for the bid bond, and 3-5% for the completion bond.

Another risk in auctions is that the projects are not implemented in time, or are implemented at a smaller scale than in the bid. To manage such risks the auctions typically include sanctions for delays in project completion or for smaller than agreed project sizes. The awarded premium shall be reduced by a constant percentage (such as 5%) each month the project is delayed from the deadline. The awarded subsidy shall be reduced by the same percentage as the project does fall below the bid capacity.

For example, if a project that was 100 kW in the bid is actually only 80 kW at the commissioning, its subsidy will be reduced by 20%, respectively.

Time frame from bidding to commissioning could be two years in both categories A and B. In category B, for large-scale auctions, the project implementation times need to be longer though, and need to be evaluated in detail. Projects should be well-planned when participating in the auctions, and two years can be considered enough time to implement small-scale projects. In larger-scale projects a slightly longer implementation time could be considered. A much longer timeframe could jeopardize the schedule and objectives.

6.2.6 Summary of auctioning process

Auctioning process is mainly the same in both categories and the table below summarises the main level choices in each category.

	Category A	Category B
Eligibility criteria	Technology-neutral as a principle, but minimum environmental and quality criteria to be defined in order to secure desired outcomes regarding emission reductions, air quality, biodiversity, forest carbon sinks, social justice etc.	
Auction demand	Two auctions per annum in category A, once a year in category B. Average of 5 MW auctioned in each auction (however the large-scale rounds will be considerably larger and will lead to the other rounds being smaller than 5 MW on average). Starting from a low level, and gradually increasing to meet the 200 MW target by 2035.	
Qualification requirements and documentation	Technical and economic. Social or other minimum requirements can be considered.	
Winner selection and contract award process	The winner selection is purely price-based and will be based on “pay-as-bid” approach.	
Remuneration of sellers and risk allocation	EUR/kW, paid up front in one instalment after the commissioning of the project.	EUR/MWh, a price premium on top of the open district heating tariff, for example for 10 years.
Time from award to implementation	Approximately 1 year	Approximately 2-3 years

To clarify the idea, here are couple of examples of the possible outcomes of an auctioning round. First example is of a Category A round, aiming to total 5 MW of heating capacity (in –15 °C) for self-consumption.

	Solution	Capacity [MW]	Premium [€/kW]
Company A	2 semi-deep boreholes (2km) + heat pumps, local low temperature heat network feeding to 4 new apartment buildings in a new district.	2 MW	100
Company B	20 * 200m boreholes + heat pump directly connected to buildings.	20*30kW= 0,6 MW	80
Company C	100 * 200m boreholes + heat pump directly connected to buildings.	100*30 kW=3 MW	110
Company D	100* 150 m boreholes + heat pump directly connected to buildings	100*20 kW = 2MW	120

In this example the full offerings of Company A and B would be chosen + 2,4 MW of company C offering meaning 80 heat pump solutions, if company C is willing to execute its offering partially.

Another example is of Category B, aiming at 20 MW of thermal capacity (in –10 °C) to the district heating network. Though we aim to get capacity, the premium is paid by energy produced in the heating season.

	Solution	Thermal capacity [MW]	Premium [€/MWh]
Company A	Deep heat (6km) geothermal	15	10
Company B	Fuel cell CHP	3	12
Company C	10* semi-deep boreholes (2 km) + heat pump(s)	10*0,5=5	8

In this case the full offerings of Company A and Company C will be chosen.

6.3 Supporting actions and measures

Helsinki clean energy map will be developed to ensure an easy identification of suitable locations for distributed heat production units and the identification of excess heat sources. For example, the map specifies land areas where boreholes of different depths can be drilled by easy notification process. The map will also include locations where the distributed heating units can be connected to the network. The connection points will be classified into different temperature level- and energy amount requirements. The idea is that the spots identified in the map have already been screened by the EC as technically feasible taking social aspects into account.

A fast-track permit- and implementation process will be established for solutions within the auctioning scheme. The executive committee will create a process that enables a fast implementation of the selected solutions including permits, technical support, communication to neighbours and other requirements set by the regulations. In these activities the executive committee will cooperate with Helsinki energy renaissance programme, as several of these actions also benefit the implementation of energy efficiency measures.

Support for connecting heating units to the district heating (supply and return pipes), cooling and electricity networks will be offered. Location-specific technical specifications, contract templates and economic details will be available as they are negotiated by the executive committee in beforehand, so that bidders can consider their economic implications when elaborating their offers. For auction winners, a direct communication channel will be established towards the district heating and cooling network operator (Helen Ltd today) to facilitate connections.

Third party access rules to the grids need to be formed so that they are transparent and support the transition towards two-directional smart heating and cooling grids. As City of Helsinki owns the grids that Helen operate, executive committee is assigned to develop these rules considering aspects of social acceptance, energy security, peak capacity and cost-efficiency. The development is supported by R&D pilots allowing, for example, the connections to return pipes, towards forming a new connection, contract and smart control models to manage the interconnected smart heating, cooling and electricity grids. Alongside, new contract types for district heating customers are actively offered to enable the heating unit renovations that support the decrease of grid temperatures. The average temperature of the heating grids should be gradually lowered by a minimum of 5 C degrees in order to improve the overall energy system efficiency and to lower the end-user costs. The energy renaissance programme can support this by offering services and support for the owners of the old buildings. Challenges coping with lower pipeline temperatures can be eased by energy efficiency measures, or by local heat pumps boosting the indoor and domestic water temperatures when necessary.

6.4 Summary of feasibility analysis

The auction criteria and their constant development throughout the implementation time ensures the **technical feasibility** of the scheme. Experts will be evaluating the criteria, the bids and the implementation of the solutions. **Financial feasibility** is ensured by allowing the most techno-economic sustainable solutions succeed in the bids. As seen in chapter 4 the overall financial feasibility is very good. As explained in chapter 6.2 and 6.1 the **legal and administrative feasibility** is very good and the iterative approach enables a further improved throughout the process if needed. The implementation of our plan is assumed to be **culturally and ethically feasible** as such. A summary of a risk analysis is found in Table 5 below.

Table 5. Summary of risk analysis.

Identified risk	Probability	Impact	Mitigation and adaptation plan
Expected energy efficiency measures of the Energy Renaissance program will not be fully achieved.	High	High	Alternative scenario modelled. Auction scheme flexible, which enables larger capacities to be auctioned, if needed.
Auctioning winners not running the systems as much as is techno-economically feasible (category B).	Low	Medium	Premium energy based in category B. Auction winner is paid per produced energy unit instead of installed capacity unit.
Risk of bottlenecks, such as drilling capacity, personnel, or other, and that the market is not able to respond to the demand.	Medium	High	Frequent, regular and foreseeable auctions.
The successful bidders do not have sufficient incentives to implement the projects after having been awarded a contract.	Low	High	Bid and completion bonds included in auctioning scheme.
The projects are not implemented in time, or are implemented at a smaller scale than in the bid.	High	Medium	Sanctions for delays in project completion or for smaller than agreed project sizes included.
Decentralised capacity less controllable than centralized production units.	Low	Low	Momentary excess generation could be either sold to neighbouring cities or stored to new large heat storage in Mustikkamaa.

7 Reliability and security of supply

Transition to climate neutral energy system poses risks, but these can be mitigated in advance. The main measure to ensure the flexibility and security of heat supply is to maintain the existing heat boiler capacity of approximately 2500 MW. They mitigate most of the risks in combination with large heat storages, demand response measures, ongoing extension of electricity transmission grid help to mitigate most, and distributed new capacity.

Reliability and security of supply covers a range of topics in the fields of supplying and distributing district heating and electricity.

Reliability and security of the supply of district heating requires necessary capacity for peak demand, adjustability of the production, back-up capacity in case of failures, and sufficient capacity to balance the supply and demand in different parts of the grid.

Existing oil and gas boilers keep providing the peak load capacity and grid balancing in the modelled scenarios. There is currently 2500 MW capacity of oil and gas boilers that operate only from 50 to 200 full load hours each year. Oil boilers would remain in the system and provide the required capacity for peak demands, grid balancing, and reserves for e.g. breakages. Gas boilers produce both during the peak loads and also when balancing quick hourly changes in the demand. Replacing these heat boilers in such a large capacity, but little use, is therefore very costly - therefore they keep serving these purposes also in our scenario as it seeks the most cost-efficient implementation of the clean heating system. Afterwards, when taking the final steps to carbon neutrality, these fossil fuels in these units could be replaced by, for example, clean synthetic fuels or other suitable solutions that are commercialised by that time.

Phasing out the coal carries a hidden risk to current balancing of the grid. Currently the large production units are in three locations (west, central, and east) on the Helsinki's coastline and smaller heat boiler units are spread around the city. Coal units are situated on west and central production nodes. Their phase out contains a risk in which the production balance shifts too much towards the east requiring further investments to grid balancing. The clean heating auctions would likely result to new capacity around the city, which is potentially very beneficial in balancing the grid and avoiding extra investments to the grid.

Oil and heat boilers are distributed in different point in the city and would serve as a back-up capacity in the case of larger systemic faults, e.g. a breakage of a major pipeline. Auctioned decentralized generation is also less vulnerable to breakages.

There is a risk that auctioned capacity would be less controllable than centralized production units, but two factors mitigate most of this risk. The potentially lower controllability of the auctioned units is a smaller issue as they would operate during the heating season as base load units when there is higher demand for the heat, and the momentary excess generation could be either sold to neighbouring cities or stored to new large heat storage in Mustikkamaa.

Another foreseeable risk from the capacity perspective, is that the project energy savings from the City's energy efficiency program will not be fully realized. In this case, the resulting peak demand would be something between the current and the projected one and the need for new capacity would be bigger than modelled here. This is a common risk in all proposals to the Helsinki Energy Challenge, and the annual auction volumes can be adjusted to compensate and mitigate this when more information on projected heat demand will be available in coming years.

In case Helsinki clean heating Executive Committee foresees challenges in the heat supply capacity, the auctioning criteria can be modified to stimulate the growth of demand response, energy storage and peak production solutions.

Reliability and security of the supply of electricity needs to be addressed well in advance as the auctioned capacity would replace existing coal-based combined heat and power plants. This would lower the electricity generation locally, while at the same time the growing heat pump capacity increases the power demand in Helsinki. Helsinki's power distribution company has already started extending the national transmission grid deeper in to the City to be prepared for this change[8]. Further extensions of 110 kV and larger electricity lines between connections to the City and the main power grid of Helsinki can be planned if required to secure the supply of the electricity if required.

Other measures to mitigate the risk of the low power supply are the new large heat storage under construction in Mustikkamaa and demand response solutions that can play significant role in balancing the power needs of the heat pumps in Helsinki. During the coldest days of the year energy storages and demand response automation controlling buildings, electric vehicle charging points and heat pump systems, can crucially lower the electricity demand. In addition, the energy efficiency improvements of the buildings lower the need for peak capacity. Many of these measures are listed in the City's Climate Action Plan[9].

8 Capacity

BEYOND fossils concept is very suitable to replace coal units Helsinki as those operate on heating season baseload units. Auctioning results to lowest cost units that are well suited to operate as heating season base load units. Auctioning approach is also very flexible and annually auctioned capacity volumes can be adjusted based on new information on the development of the heat demand.

[8] https://www.helensahkoverkko.fi/uutiset/2019/s%C3%A4hk%C3%B6verkko-kasvaa-kaupungin-kanssa
[9] https://www.myhelsinki.fi/en/think-sustainably/making-helsinki-carbon-neutral#:~:text=The%20goal%20of%20Helsinki%20City,in%20terms%20of%20reducing%20emissions.

District heating systems requires necessary capacity for cheap base load generation, for flexible intermittent generation, and for peak demand generation for the coldest hours of the year. Further, the system must be adequately distributed to be able to balance the supply and demand in each consumption node and be robust enough to be able to provide heat even in case of breakages, e.g., breaking pipe, or an unplanned shutdown of any unit.

The current grid has large reserve capacity with 3.9 GW capacity in 2020 and 2.6 GW peak demand in the released open data[10] for 2016 (**Figure 9**). The largest share of the capacity is oil boilers (1.6 GW_{DH}, 40% of total) that produce during the peak demands and balance the supply and demand in different parts of the grids. They also provide reserves in case of breakages.

Current coal units are the second largest capacity group (0.9 GW_{DH}, 25% of total) producing heat as base load units during the heating season (~7 months, ~4000 hours). Helen Ltd has committed to 350 MW_{DH} investments of the bio boilers that are expected to partly replace the coal. Clean heating auctions are very suitable to replace the rest as the lowest cost criteria for projects is the best approach for heating season base load units.

City's large natural gas combined cycle (NGCC) units and gas boilers share the title of the third largest capacity group (both 0.9 GW and 15% of the total). Large NGCC's are operated similarly than coal units, and the cost order between them varies depending current fuel prices, tax levels, and CO2 prices. However, another of these NGCCs is the main producing unit in the eastern Helsinki heating grid. Gas boilers are very flexible units and they are used to adjust the quick changes in demand, e.g. in work-day mornings when demand of heating and hot water sharply increases. These morning spikes can be few hundred MW and require very flexible and adjustable units to supply the heat.

Increased auction volumes towards 2035 would begin to lower the operational hours of the NGCC units. In our scenario, the smaller one would phased out by 2035 due to low operation hours and the bigger NGCC unit is reconfigured to serve heat to both larger west Helsinki DH grid and smaller east Helsinki DH grid. The natural gas in remaining units can be replaced later by biogas or/and by clean synthetic gas.

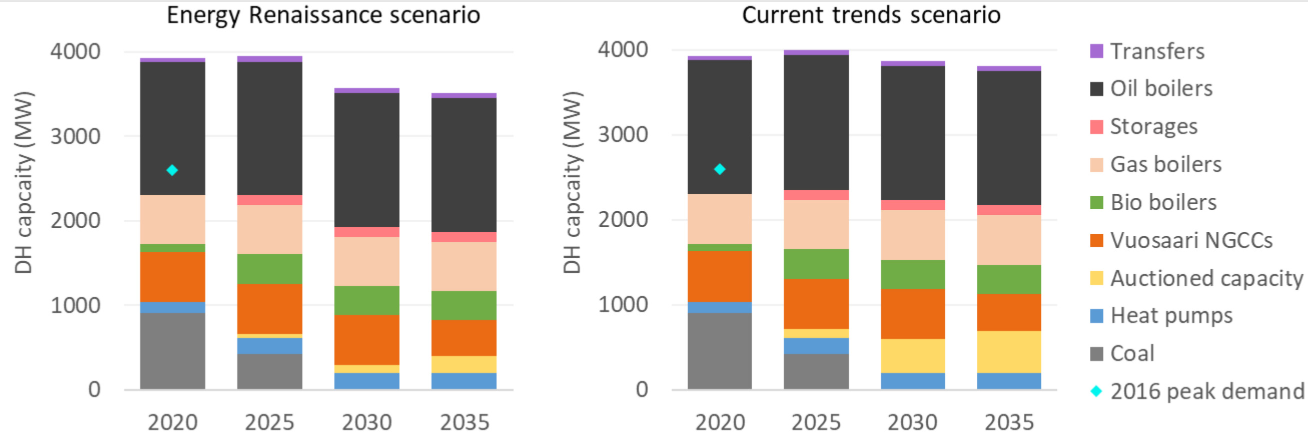

Figure 8. District heating generation capacity 2020-2035 and peak demand in 2016. City's energy efficiency program is expected to decrease the peak demand from 2016 values in 2030 and 2035.

[10] https://www.helen.fi/en/company/responsibility/current-topics/open-data